

General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

FLOW OF VISCOUS GAS IN THE REGION OF A SLOT
WITH STRONG SUCTION

L.P. Kozlov

(NASA-TM-75241) FLOW OF VISCOUS GAS IN THE
REGION OF A SLOT WITH STRONG SUCTION
(National Aeronautics and Space
Administration) 8 p HC A02/MF A01 CSCL 20D

N78-21411

Unclas
G3/34 15897

Translation of "Tehiya v'yazkogo gazu v raioni
shchilini pri intensivnomu vidsmoktuvanni," Dopovidi Akademii
Nauk Ukrain's'koi RSR, Seriya A. Fiziko-tekhnichni
ta matematichni nauki, No. 6, 1973, p. 538-541.



1. Report No. NASA TM-75241	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle FLOW OF VISCOUS GAS IN THE REGION OF A SLOT WITH STRONG SUCTION		5. Report Date April 1978	
		6. Performing Organization Code	
7. Author(s) L.P. Kozlov, Institute of Hydromechanics Academy of Sciences UkrRSR		8. Performing Organization Report No.	
		10. Work Unit No.	
9. Performing Organization Name and Address Leo Kanner Associates Redwood City, California 94063		11. Contract or Grant No. NASw-2790	
		13. Type of Report and Period Covered Translation	
12. Sponsoring Agency Name and Address National Aeronautics and Space Admin- istration, Washington, D.C. 20546		14. Sponsoring Agency Code	
15. Supplementary Notes Translation of "Techiya v'yazkogo gazu v raioni shchilini pri intensivnomu vidsmoktuvanni," Dopovidi Akademii Nauk Ukrains' koi RSR, Seriya A. Fiziko-tehnichni ta matematichni nauki, No. 6, 1973, p. 538-541. (A73 - 42283)			
16. Abstract The flow of a perfect viscous gas was studied in the region of a slot with strong suction. The distribution fields of vel- ocities and temperatures are computed for the case of thermal- ly insulated and heat-conducting surfaces. The dependence of the flow characteristics on the suction gas discharge is ob- tained for a single slot with strong suction.			
17. Key Words (Selected by Author(s))		18. Distribution Statement Unclassified-Unlimited	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	22. Price

ORIGINAL PAGE IS
OF POOR QUALITY

NASA-HQ

FLOW OF VISCOUS GAS IN THE REGION OF A SLOT WITH STRONG SUCTION

L.P. Kozlov

Institute of Hydromechanics, Academy of Sciences UkrRSR

On the basis of the continuity equation and simple geometric /538* considerations, G. Lachmann [1] developed an approximate method of calculation of the characteristics of a laminar boundary layer in an uncompressed fluid near a slot with suction. With the aid of the law of conservation of momentum, W. Colemann [2] succeeded in more strictly grounding the method mentioned. Both studies were explained in monograph [3]. This study is devoted to a theoretical investigation of the flow of a perfect viscous gas in the region of a slot with strong suction. A solution was obtained for an incompressible fluid, as a separate case.

The differential equations for the case of nonstationary flow of a viscous gas, in the absence of general forces, take the form [4]:

$$\left. \begin{aligned} \rho \frac{du}{dt} &= -\frac{\partial p}{\partial x} + \frac{\partial}{\partial x} \left[\mu \left(2 \frac{\partial u}{\partial x} - \frac{2}{3} \operatorname{div} \vec{w} \right) \right] + \\ &+ \frac{\partial}{\partial y} \left[\mu \left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \right) \right] + \frac{\partial}{\partial z} \left[\mu \left(\frac{\partial w}{\partial x} + \frac{\partial u}{\partial z} \right) \right], \\ \rho \frac{dv}{dt} &= -\frac{\partial p}{\partial y} + \frac{\partial}{\partial y} \left[\mu \left(2 \frac{\partial v}{\partial y} - \frac{2}{3} \operatorname{div} \vec{w} \right) \right] + \\ &+ \frac{\partial}{\partial z} \left[\mu \left(\frac{\partial v}{\partial z} + \frac{\partial w}{\partial y} \right) \right] + \frac{\partial}{\partial x} \left[\mu \left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \right) \right], \\ \rho \frac{dw}{dt} &= -\frac{\partial p}{\partial z} + \frac{\partial}{\partial z} \left[\mu \left(2 \frac{\partial w}{\partial z} - \frac{2}{3} \operatorname{div} \vec{w} \right) \right] + \\ &+ \frac{\partial}{\partial x} \left[\mu \left(\frac{\partial w}{\partial x} + \frac{\partial u}{\partial z} \right) \right] + \frac{\partial}{\partial y} \left[\mu \left(\frac{\partial v}{\partial z} + \frac{\partial w}{\partial y} \right) \right], \end{aligned} \right\} \quad (1)$$

*Numbers in the margin indicate pagination in the foreign text.

where $\vec{w} = \vec{i}u + \vec{j}v + \vec{k}w$ is the velocity vector; u, v, w are the projections of the velocity vector on the axes of a rectangular coordinate system; p is the pressure; ρ is the density of the gas; μ is the dynamic coefficient of viscosity of the gas.

These equations must be supplemented by the equation of continuity

$$\frac{\partial \rho}{\partial t} + \text{div}(\rho \vec{w}) = 0 \quad (2)$$

and the energy equation

$$\rho C_p \frac{dT}{dt} = \frac{dp}{dt} + \left[\frac{\partial}{\partial x} \left(\lambda \frac{\partial T}{\partial x} \right) + \frac{\partial}{\partial y} \left(\lambda \frac{\partial T}{\partial y} \right) + \frac{\partial}{\partial z} \left(\lambda \frac{\partial T}{\partial z} \right) \right] + \mu \Phi, \quad (3)$$

where

$$\Phi = 2 \left[\left(\frac{\partial u}{\partial x} \right)^2 + \left(\frac{\partial v}{\partial y} \right)^2 + \left(\frac{\partial w}{\partial z} \right)^2 \right] + \left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y} \right)^2 + \left(\frac{\partial w}{\partial y} + \frac{\partial v}{\partial z} \right)^2 + \left(\frac{\partial u}{\partial z} + \frac{\partial w}{\partial x} \right)^2 - \frac{2}{3} \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} \right)^2 -$$

/539

is a dissipative function; C_p is the specific heat of the gas at constant pressure, per unit mass; λ is the coefficient of thermal conductivity.

Besides, in considering the gas to be perfect, we will have

$$p = \rho RT, \quad (4)$$

where R is the gas constant; T is the absolute temperature.

Finally, there is the correlation required for a closed system of equations to give the empirical relation

$$\mu = \mu(T). \quad (5)$$

The boundary conditions were implemented for the region $x_0 \leq x \leq x_0 + S$, where x_0 is the coordinate of the leading side of the slot; S is the width of the slot.

Two cases are considered in the articles:

a) Heat insulation of the surface

$$\left. \begin{array}{l} \text{with } y=0 \quad u=0; \quad v=-v_0; \quad \frac{\partial T}{\partial y}=0; \\ \text{with } y=\infty \quad u=U_\infty; \quad \frac{\partial u}{\partial y}=0; \quad T=T_\infty. \end{array} \right\} \quad (6)$$

In this case, convective heat transfer is disregarded, on condition of suction of the gas through the slots;

b) Heat conduction of the surface

/540

$$\left. \begin{array}{l} \text{with } y=0 \quad u=0; \quad v=-v_0; \quad T=T_{cr}; \\ \text{with } y=\infty \quad u=U_\infty; \quad \frac{\partial u}{\partial y}=0; \quad T=T_\infty. \end{array} \right\} \quad (7)$$

These assumptions are made in the subsequent calculations: the gas flow is stationary and smooth; the dynamic coefficient of viscosity of the gas is reduced in proportion to density; no effect of the distant gas flow develops in the section $x = x_0 + S$; the Reynolds number, based on the width of the slot and the velocity of the incoming flow, an order of magnitude higher than the dimensionless width of the slot, relative to the loss of impulse on the leading edge of the slot; the suction in the slot is stronger, so that $\frac{Q_i \delta_{i,2}^{xx}}{S_i v} \gg 0,5$, where Q_i is the bulk flow rate of the gas sucked through the i -th slot; v is the kinematic coefficient of viscosity of the gas; $\delta_{i,2}^{xx}$ is the loss of impulse in the area of the trailing edge of the i -th slot.

After simplification of system of equations (1)-(5), on the basis of the assumptions indicated and calculating boundary conditions (6)-(7), the velocity and temperature distribution fields across the boundary layer were calculated, as a function of the Mach number and the temperature ratio T_{ct}/T_∞ . As an example, the

results of calculations for $M = 2$ and temperature ratio $T_{ct}/T_\infty = 1.0-1.8$, in the section near the trailing edge of the slot on a heat conducting surface, is plotted in Fig. 1, in the form of continuous curves. For comparison, similar data for $M = 3$ and temperature ratio $T_{ct}/T_\infty = 1.6$, is shown in the same graph by a dashed line.

The corresponding data for a heat insulated surface and $M = 1$ and $M = 2$ also are plotted in Fig. 1, by means of dot-dashed lines.

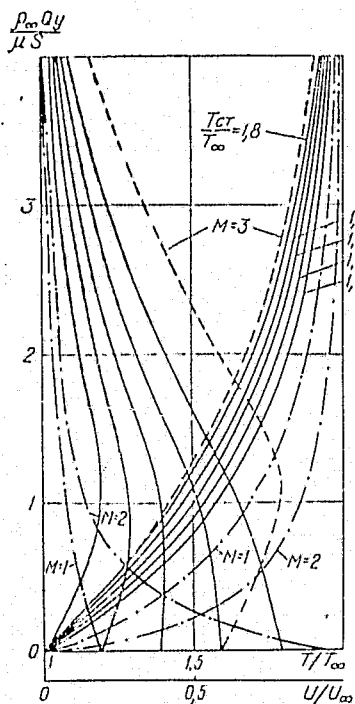


Fig. 1.

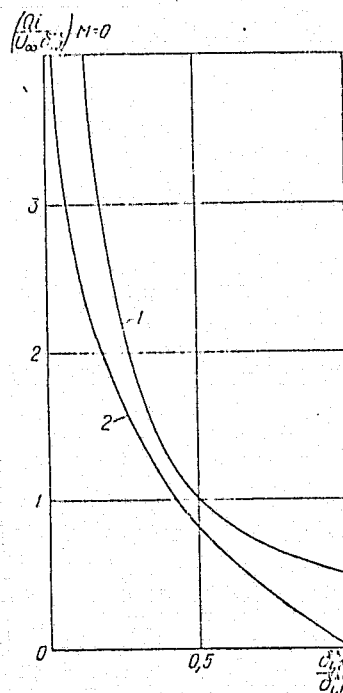


Fig. 2.

Besides, the loss of gas suction through the i -th slot Q_i vs. the loss of impulse on the trailing and leading edges of the slot $\delta^{xx}_{1,2}/\delta^{xx}_{1,1}$ was obtained by computer. This relation for an incompressible fluid is presented in Fig. 2 (curve 1) in dimensionless form. For comparison, the relation obtained by Lachmann [1] (curve 2) is presented in the same graph. From analysis of these results, it should be noted that, in the interval of values of $\delta^{xx}_{1,2}/\delta^{xx}_{1,1} = 0.3-0.6$, curves 1 and 2 differ by 10-25%. In different intervals of

change of $\delta^{xx}_{i,2}/\delta^{xx}_{i,1}$, the divergence between curves 1 and 2 is more evident. It is evident that curve 1 is entirely satisfactorily confirmed by actual experiments.

For a compressed gas, a relationship is obtained in the form

$$\frac{Q_i}{U_{\infty} \delta_{i,1}^{xx}} = 2k \left(M, \frac{T_{ct}}{T_{\infty}} \right) \left(\frac{Q_i}{U_{\infty} \delta_{i,1}^{xx}} \right)_{M=0} \quad (8)$$

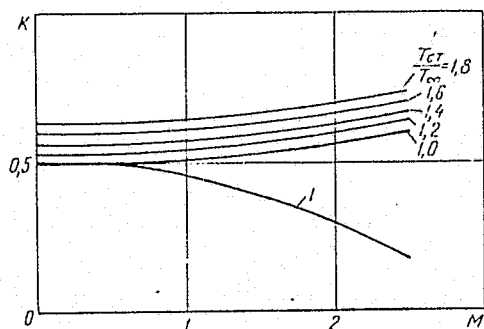


Fig. 3.

Coefficient K vs. Mach number and the ratio of the surface and incoming flow temperatures T_{ct}/T_{∞} is presented in Fig. 3, for a heat insulated (curve 1) and a heat conducting (the other curves) surface.

ORIGINAL PAGE IS
OF POOR QUALITY

REFERENCES

1. Lachmann, G., Aeron. Eng. Rev. 13/8, (1954).
2. Colemann, W., J. Roy. Aeronaut. Soc. 61, 557 (1957).
3. Kozlov, L.F., Laminarnyy pogranichnyy sloy pri nalichii otsasyvaniya [The Laminar Boundary Layer with Suction], Naukova dumka Press, Kiev, 1968.
4. Shlikhting, G., Teoriya pogranichnogo sloya [Boundary Layer Theory], Nauka Press, Moscow, 1969.